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Understanding Innovations in Traditional Agriculture of Northeast India - the Case for Sustainable Development[†]

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1. Introduction

The meaning of economic development has undergone three important shifts over the post-war period. The first phase (1950 to early 1960s) equated economic development with economic growth, as defined by a sustained increase in real per capita gross national income. The second shift (late 1960s to early 1970s) emphasized "growth with redistribution". Economic growth was still the main objective, but the emphasis now was to be on growth that would improve the standard of living of the poorest income groups. Agriculture became the priority sector; since it was having the potential to eliminate malnutrition and hunger, absorb surplus labour and boost foreign exchange earnings (Johnston and Kilby, 1975). A more radical shift being witnessed from late 1970s was the "basic needs" approach. The objective is a "new kind of economic growth", enabling basic needs to be achieved by redistributing resources within the social sectors and by a reorientation of growth, so that the deprived participate.

A concern for 'sustainability' represents the most recent shift in development thinking (WCED, 1987a). Besides the emphasis on improving the livelihoods of the poor, this approach additionally argues that lasting improvement cannot occur in the Third World countries unless the strategies which are being formulated and implemented are environmentally and socially sustainable; that is they maintain and enhance the natural and human resources upon which development depends.

The opening up of the global economy exerts immense pressure on the harnessing of our natural resources. This leads to the conscious design and development of technologies and innovations in such a way that they are equipped to have an economic edge over the other. So it would not be surprising to connote the term 'innovation' with the economic novelty of a product, process or both. This has resulted in the formation of a new culture among people – technology users and generators, who see technologies and innovations as tools of getting maximum benefits from exploiting the scarce resources available around them. This outlook appears to be rather alarming and dangerous because critical questions of sustainability, equity and stability are not taken into consideration. The Green Revolution introduced in India during the mid 1960s is a stark example of adopting a package of technical innovations

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that have the novelty of producing higher yields but also causes irreversible environmental damages. The scientists and the innovation administrators concerned did not anticipate these disastrous results then.

Little use was made of the indigenous knowledge when food production and subsistence agriculture was for home consumption and local market. However, with world market opening up and globalisation picking up, agricultural research is tuned towards ensuring monetary gains through rapid increase in food production. However this approach is short sighted because it does not ensure sustainable development as an equally important goal as increasing productivity.

Even in such an environment of wanton exploitation of resources, we are fortunate to have certain indigenous agricultural practices still in vogue in certain parts Northeast India. The adoption of these indigenous practices does entail minimal ecological damages. They have been tested with time and are seen to have high degree of sustainability embedded in them. It would be worthwhile to study these practices and also make attempts to scale them up and /or incorporate their sustainable ingredients into our modern agricultural innovations/ technologies. Hence there is need to reassess the modern agricultural innovations so that sustainability dimension is seriously taken into account in an era of environmental degradation taking place rapidly.

The Northeast India region comprising of the eight states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura lies between 21.57^{o} and 29.30^{o} N latitude and 88.00^{o} and 97.30^{o} E longitude. It covers a geographical area of about 0.26 million sq km accounting 7.9% of India's total geographical area. About 70% of the region is hilly, and the topography varies within each state. In 2001, the population of the region is 38.98 million (3.75% of India's total population) and the population density is 149 per sq km. The population comprises of several communities and tribal groups of people. It is a home to over 200 of the 635 tribal groups in India speaking a variety of Tibeto-Burman languages and dialects with a strong tradition of social and cultural identity marked by diversity in customs, cultures and traditions.

Richly endowed with natural resources, the region is identified as one of the world's biodiversity hotspots; it hosts species-rich tropical rain forests that support diverse flora and fauna and several crop species. The average annual rainfall of the region varies from 200 to 12000 mm. The climatic conditions range from sub-tropical to sub-temperate types of climate.

2. Methodology

Given the above context, the paper is then designed with the following objectives, *viz.*, (i) to call attention to the ecological damages caused by a package of technical innovations (in this case, the Green Revolution) that are over-characterised with economic gains; (ii) to present the indigenous agriculture of Northeast India so as to highlight the unique sustainability elements embedded in them; and (iii) to stress the need for exploring the ways and means of incorporating and scaling up these traditional technologies/innovations in view of their salient sustainable features and in response to today's intense need for addressing the sustainability question.

The Green Revolution adopted in India is taken as a package of technical innovations that are over-characterised with economic gains/ profits and the data are taken from secondary sources. The data on traditional practices of the indigenous agriculture are collected from published data in addition to primary data collected during June-July 2008 through semi-structured interview schedules and discussions with farmers and key informants who are located at different places in Northeast India. This information along with those obtained through interviewing personnel from the State agriculture departments and researchers are analysed to explore and suggest ways of scaling up these traditional agricultural practices so as to be able to address the sustainability questions already highlighted.

3. The Green Revolution (a package of technical innovations) – a novelty in feeding hungry mouths at the cost of degrading natural resources

The shifts (discussed in the introduction section) in the overall development thinking have been reflected by similar concerns within the narrower focus of agricultural development. The goal of increasing per capita income was to be matched by the rising per capita food production, and the means was the Green Revolution, largely funded by the international donor community and engineered by the International Agricultural Research Centres (Conway and Barbier, 1990). In essence it focused on three interrelated actions (Conway, 1987):

- breeding programmes for stable cereals that produced early maturing, day-length sensitive and high yielding varieties (HYVs).
- the organization and distribution of packages of high pay-off inputs, such as fertilizers, pesticides and water regulation.
- implementation of these technical innovations in the most favourable agroclimatic regions and for those classes of farmers with the best expectations of realizing the potential yields.

The impact of the Green Revolution in the Third World, particularly on wheat and rice production, has been phenomenal; between one-third and one-half of the rice areas in the developing world are planted with HYVs. In the eight Asian countries that produce 85 percent of Asia's rice (Bangladesh, China, India, Indonesia, Myanmar, Philippines, Sri Lanka and Thailand) HYVs add 27 million tonnes annually to production, fertilizers another 29 million tonnes and irrigation 34 million tonnes (Pinstrup-Andersen and Hazell, 1987). Per capita food production in the developing countries has risen by 7% since the mid 1960s, with an increase of over 27% in Asia.

These imperative results however, have been associated with significant problems of equity, stability and sustainability. For example, while producers have widely adopted the new HYVs irrespective of farm size and tenure, factors such as soil quality, access to irrigation water and other biophysical – agroclimatic conditions have been formidable barriers to adoption. The higher productivity of rice and wheat has led many farmers to substitute these cereals for other staples and for more traditional mixed patterns of cropping.

Newly discovered environmental calamities and health hazards added more dark colours to an already gloomy picture. Intensive fertilization resulted in nitration, in turn causing eutrophication of freshwaters, streams and lakes. Excessive amounts of pesticides, applied irresponsibly over large areas, created health hazards for rural inhabitants. Moreover, the energy necessary for the production of nitrogen-based fertilizers, for running agricultural machinery, for fuel, and for operating irrigation facilities was severely limited (Glaeser, 1987).

Intensive monocropping with genotypically similar varieties has also led to increasing incidence of pest, disease and weed problems, sometimes aggravated by pesticide use. Severe outbreaks of the brown plant hopper occurred on rice in the 1970s, with losses in 1977 in Indonesia of the order of 2 million tonnes. Plant hoppers are naturally controlled by wolf spiders and a variety of other natural predators, which are destroyed by many of the pesticides commonly used in rice.

There were then signs of diminishing returns to the HYVs and high pay-off inputs in intensive production. The experience on less well-endowed farms, suggests there are real limits to replicating the successes of current green revolution technologies and packages in more marginal agricultural areas.

For thousands of years, farmers had produced their own seeds on their own lands on the strategy of conserving and enhancing genetic diversity and self-renewability of crops. The shift from indigenous varieties of seeds to the Green Revolution varieties involved a shift from a farming system controlled by farmers to one controlled by agrochemical and seed corporations, and international agricultural research centres. A free resource reproduced on the farm, seeds were transformed into a costly input to be purchased.

Traditional framing systems are based on mixed and rotational cropping systems of cereals, pulses, oilseeds with diverse varieties of each crop. The Green Revolution package, on the other hand, is based on genetically uniform monocultures. The nitrogen fixing capacity of pulses of the traditional farming systems is an invisible ecological contribution to the yield of associated cereals.

In HYVs, the increase in marketable output of grain has been achieved at the cost of decrease in biomass for animals and soils and the decrease of ecosystem productivity due to over-use of resources. Some varieties, which are good yielder of grains, suffer from the drawback of being low in respect to straw (Iyengar, 1980).

Diversity was a central principle of the breeding strategies adopted by the farmers. This diversity contributed to ecological stability, and hence to ecosystem productivity. Less diversity results in higher vulnerability to instability, breakdown and collapse. Genetic diversity is destroyed by the Green Revolution at two levels – first by the transformation of mixed and rotational cropping of wheat, bajra, jowar, barley, pulses, and oilseeds into monocultures and multicropping of wheat and rice, and second, by the conversion of wheat and rice from diverse native varieties suited to different soil, water and climatic conditions to monocultures of single varieties derived from the exotic dwarf varieties of CIMMYT and IRRI.

Large-scale monocultures of exotic varieties of wheat have turned minor diseases such as Karnal bunt into epidemic proportions. Leaf blight, Brown rust and Loose smut are the other diseases. The vulnerability of rice to new pests and diseases due to monocropping and a narrow genetic base is also very high. In contrast to the local traditional varieties, the HYVs and hybrids have only three to five years' life in the field, as pests and diseases overtake them. Thereafter they became susceptible to the new races and biotypes of pests and diseases.

There is linkage between heavy use of fertilizers and vulnerability to pests. The excessive fertilizer uptake of the new varieties is found to contribute to disease vulnerability. Chemical fertilizers, which are an essential part of the package of the new seed technology, thus contribute to pest vulnerability by reducing resistance. The Green Revolution strategy fails to see the ecology of pests as well as that of pesticides. It also fails to recognise that pests have natural enemies with the unique property of regulating pest populations. Having destroyed nature's mechanisms for controlling pests and diseases, the seeds of HYVs became mechanisms for breeding new pests and creating new diseases.

After a few years of bumper harvests in Punjab, crop failures at a large number of sites were reported, despite liberal applications of NPK fertilizers. The new threat came from micronutrient deficiencies caused by rapid and continuous removal of micronutrients by HYVs. The Green Revolution has also resulted in soil toxicity by introducing excess quantities of trace elements in the ecosystem. Fluorine, aluminium, boron, iron, molybdenum and selenium toxicity has built up with Green Revolution practices. Sustainable agriculture is based on the recycling of soil nutrients. This involves returning part of the nutrient that comes from the soil back to the soil, either directly as organic fertilizer, or indirectly through the manure from farm animals. The Green Revolution created a perception that soil fertility is produced in chemical factories, and agricultural yields are measured only through marketed commodities. The "land-augmenting" technology has proved to be a land-degrading and land-destroying technology. Nitrogen based fertilizers release nitrous oxide to the atmosphere that is one of the greenhouse gases causing global warming (Shiva, 1991).

The Green Revolution was based on the expansion and intensification of irrigation from surface as well as ground water. Compared to the earlier varieties needing protective irrigation as an insurance against crop failure, the new seeds need intensive irrigation as an essential input for crop yields. The dramatic increase in water use has led to a total destabilisation of the water balance in the region. The water cycle can be destabilised by adding more water to an ecosystem than the natural drainage potential of that system. This leads to desertification through waterlogging and salinisation of the land. Today more than one third of the world's irrigated land has salt-pollution problems that diminish the productivity of the soil and in extreme cases, ruin it forever.

While the increase in productivity was the primary objective of the Green Revolution, in terms of resources and energy, the productivity actually declined. The increase that was achieved in the early phases was at the level of financial returns. However, the ecology of the Green Revolution demanded increasing costs of inputs and resulted in decreasing profits for the farmers. In less than two decades, the Green Revolution had become financially and ecologically unviable, though it succeeded in the production of surpluses of specialised crops in a specialised region for a short period.

Development practitioners and policy makers now commonly acknowledge the problems arising out of and the failures of the Green Revolution. The report of the World Commission on Environment and Development – the "Brundtland Report" argues for "environmentally sustainable economic growth" for the Third World and stress that, "although the agricultural resources and the technology needed to feed growing populations are available", global food security requires "increasing food production to keep pace with demand while retaining the essential ecological integrity of production systems" (WCED, 1987a). The arguments in favour of promoting a more sustainable development approach, particularly the dismantling of policies and incentive structures that stand in its way, are also slowly being accepted by the international donor community (Davies and Schirmer, 1987; WCED, 1987b).

4. Indigenous agricultural systems of Northeast India – examples of innovations for sustainable development

Four important indigenous agricultural systems *viz.*, Rice based farming system of the Apatanis, Zabo based terrace wet rice cum fish culture of the Chakhesangs, Bamboo drip irrigation system of Jaintia and Khasi Hills in Meghalaya and Alder-based *jhum* system of the Angamis of Nagaland are briefly presented below with the purpose of identifying the inherent characteristics of sustainability embedded in them and exploring ways to replicate them elsewhere.

4.1 Rice based farming system of the Apatanis

The Apatani plateau occupies about 27 sq km area located at an altitude of about 1525 m above mean sea level in the humid tropic climate of the Lower Subansiri district of Arunachal Pradesh. The Apatani tribals inhabit the plateau and their population density is 554 persons per sq km against an average of 10 persons of the state. The plateau has 21 villages with more than 30,000 families and an average of 66 persons per family (Mishra and Sharma, 1999; Mishra *et. al.*, 2004).

The farmers grow wet rice, integrated with fish culture in terraces and finger millets on the risers/ terrace bunds. Only indigenous highly shattering long duration rice varieties (190 – 278 days) are grown. In February, nursery beds are prepared wet and sown with dry seed following 75-80 kg / ha seed rates. Transplanting is done in April-May. Two categories of paddy are cultivated – *Mipya* (early maturing varieties) and *Emo* (late maturing varieties). The area under terrace rice cultivation is around 1737 ha. The portions of area covered by different local rice varieties are *Emo* (68%) followed by *Pyaping* (15%) and *Payat* (10%) with corresponding yields of 5.2, 4.0 and 3.2 t/ha. Risers or terrace bunds are used for growing finger millets. These bind the soil and also suppress weeds growing on the bunds. Millets are used for local breweries.

Within one month of transplanting of paddy, finger lings of size 40-50 mm are stocked. Mainly common carp (*Cyprinus carpo*) are reared in the terraces along with the cultivation of paddy. The fishes in four months time attain the size/weight of about 200 gm and are then harvested. In terraces where long duration rice varieties are grown, the fishes are harvested twice in a year yielding about 150 – 200 kg/ha/season. There is no cost of maintenance as the fishes feed on naturally available organisms such as phytoplankton and other microorganisms. No additional feeding is done.

Terraces prepared in the main valley are quite broad, perfectly levelled and provided with strong bunds. The slope of land in the main valley ranges between 1-8%. Puddling and levelling of terraces is done manually with the help of indigenous wooden tools. Fish channels across the terrace are dug with wooden crowbar having flattened tip. Every stream arising from the surrounding hills is tapped, channelised at the rim of the valley and diverted to the terrace fields by a network of primary, secondary and tertiary channels.

Nutrient management of the terraces is done mainly through recycling of agricultural wastes. Paddy straw is kept in the field to be decomposed and finally incorporated in the soil during land preparation. Burning of undecomposed straw is also practised. Pig and poultry droppings, rice husks, kitchen waste, ash, weeds removed during weeding are also recycled in the fields every year. The domestic sewage from the villages, which are normally located at a higher elevation, is directed to the fields. This adds organic matter to the soil in the terrace and also provides feed to the fishes reared in the terraces.

In order to maintain and regulate water supply to the fields, the surrounding hills are covered with forests. Farmers have taken up plantation of *Terminalis myrinalia*, *Ailanthes excelsa*, *Michelia* sp., *Mangolia* sp., pines and bamboos. They prohibited cutting down certain trees like *Kiira* (*Castapnopsis* sp.) that has elongated deep root system and thus helps in conserving water. In order to conserve the forests the Apatanis have taboos that restrict cutting down of trees. Severe punishments and penalties are imposed on defaulters. The economy base of the Apatanis thus comprises of the sustainable integration of land, water and farming systems.

4.2 Zabo based terrace wet rice cum fish culture of the Chakhesangs

Zabo, an indigenous farming system that combines forestry, agriculture, fishery and animal husbandry appears to have originated in Kikruma village having an annual rainfall of 1613 mm and located at an altitude of 1270 m above mean sea level in Phek district of Nagaland. The Chakhesang tribals who inhabited this village have developed this system and it is being practised in an area of 957.9 hectare. The word “Zabo” means impounding of water (Dabral, 2002).

The Zabo system consists of a protected forestland towards the top of the hill, water-harvesting tanks in the middle and cattle yard and paddy fields at the lower side. When it becomes difficult to get a suitable location for construction of water storage tanks, the runoff from the catchment area is directly taken to the paddy fields for storage and irrigation later during the cropping period. Special techniques for seepage control in the paddy plots are followed. Paddy husk is used on shoulder bunds and puddling is done thoroughly.

The catchment area that is generally 1.5 ha or more is kept under forest cover without disturbing by activities such as cutting and burning of trees. This area serves as water source for the tanks. Cattle, pigs, poultry birds are sometimes let loose in the forest. Near the catchment area (mid-hill), silt retention tank and water harvesting tank are dugout with the formation of earthen embankments. Silt retention tanks are constructed at two or more points and the water is kept for 2 or 3 days in these tanks before being transferred to the main tank. The silt retention tanks are cleaned annually and the desilted materials, which have good amount of organic matter and nutrients, are transferred in the terrace fields. In constructing the water-harvesting tank, the bottom surface is properly rammed and sidewalls are plastered with paddy husk to minimise the loss of water through seepage.

The cattle enclosures fenced with wood and branches or bamboo where the farmers keep their cattle on rotational basis are constructed on a little lower side of the water-harvesting pond. The water from the pond is passed through the cattle yard before taking it to the rice field for irrigation. The water carries with it the dung and urine of the animals to the fields through split bamboo channels. This serves as good source of nutrition for the crops.

Paddy fields, which are generally 0.2 to 0.8 ha in size, are located at the lower elevations. The fields are thoroughly rammed at the time of puddling through human treading, cattle in-group and wooden sticks to create a hard pan in order to avoid percolation of water. Using of paddy husk checks seepage losses from shoulder bunds. Only one crop of rice is grown and the common local variety is "*Tanyekemucah*". This variety matures in about 180 days. The normal seeding rate is 60 kg per ha. Transplanting is done in June at about 12 cm x 12 cm to 18 cm x 18 cm spacing. Two supplementary irrigations are given from the water-harvesting tank. About 10 cm deep water is maintained in the paddy fields. The yield of paddy ranges between 3-4 tons per hectare.

Majority of the farmers practise fish culture in their wet rice terraces. A small pit is dug in the middle of the rice field and fish fingerlings are put in the fields. When the water is drained out from the fields before intercultural operations and harvesting of the paddy crop, the fish remain in the pit. Farmers normally obtain 50 – 60 kg of fish per hectare.

The Zabo farming system is a traditional agriculture and forestry land use system which has an inbuilt water harvesting and recycling systems with well founded conservation base to control soil erosion, proper management of soil fertility and available water. It is a viable practice of resource management and maintenance of ecological balance.

4.3 Bamboo drip irrigation system of Jaintia and Khasi Hills of Meghalaya

Bamboo drip irrigation system is practised mainly in the Jaintia and Khasi Hills of Meghalaya for the last 200 years. This is a useful irrigation system in a place where there is water scarcity and soils are poor in water holding capacity, the topography is rocky and undulating and irrigation is required for crops that need relatively less water. Betel vines, aracanuts, black pepper and other plantation crops are irrigated with this system in which water trickles or drips drop by drop at the base of the crop. This is achieved by having holes at appropriate points. Water is conveyed to the site of actual use without leakage and loss on the way. Water from the natural stream located at a higher elevation is conveyed through gravitational flow with the use of bamboo channels supported on ground surface by wooden or bamboo supports, to the plantation sites. Water distribution is done with the use of bamboo channels, bamboo supports, water diversion pipes and strips. The whole system enables the distribution of 15 to 25 litres of water per minute depending on the availability of water resource and the number of plants to be irrigated (Singh, 1989).

The locally available bamboo is used in fabricating the channels for irrigation system. Bamboo of larger diameter is used at the start for maximum quantity of water in the beginning and the size can be subsequently reduced as per requirement of water. It takes about 15 days for 2 labours to install the system in a hectare of land. Most of the materials used in installing the system last around three years. Once laid out the system works round the clock if so desired. The maintenance cost is very minimal; a little care is sufficient to keep the system in good condition (Saxena *et. al*., 2003).

4.4 Alder-based *jhum* system of the Angamis of Nagaland

The alder-based *jhum* system, a unique and highly productive form of *jhum* (shifting cultivation or swidden agriculture) has been developed in Khonoma village located about 20 km west of Kohima, the capital town of Nagaland. The village is interspersed with alder trees; some of these are more than 200 years old and are still healthy. The system provides at least 57 food crops to supplement the rice grown in nearby wet terrace rice cultivation (NEPED and IIRR, 1999). Normally a *jhum* farmer cultivates the *jhum* fields for two years within a nine-year cycle (1:4 ratio of cropping to fallow). But the alder system allows two harvests in two out of every four to five years (1:1 ratio of cropping to fallow).

The alder (*Alnus nepalensis*) is a non-leguminous, large deciduous tree that grows well on cooler parts of the northern temperate region at high altitudes ranging from 800 to 3000 m. It is a pioneer species of degraded lands and does not require fertile soil. It is a rapid coloniser of gravelly lands and old cultivated lands that are frequently unstable. The alder tree has root nodules, which improve soil fertility by fixing atmospheric nitrogen into the soil. The tree sheds its leaves to retain moisture and mulches and add abundance of humus to the soil. The wood is used in various domestic needs such as fuelwood, charcoal burning and construction. The mature wood is used for making luxury furniture.

In a *jhum* field located in hills above 1000 m the alder saplings collected from nursery or from the wild are planted maintaining a spacing of 3-4 m between plants and 5-6 m between rows. The trees are allowed to grow for 10 years or until they attain rough fissures on the bark after which the initial pollarding is initiated. In the first year in a *jhum* plot, alder trees are pollarded (cut off from the main trunk) at a height of 2 m from the ground before or after the slash and burn operation. Primary food grain crops and secondary crops such as vegetables are grown as mixed crops in the burned fields. The cropping operation is repeated in the second year. The field is left fallow for two to four years to allow the alder trees to grow for pollarding and cropping in the subsequent cycle.

The practice of pollarding of alder trees is done in two phases – initial pollarding and cyclical/subsequent pollarding. Young trees are pollarded for the first time when the bole circumference reaches 50 to 80 cm and bark develops rough fissures, usually at the age of 7 to 10 years. The next pollarding is after four to six years. When the main trunk is cut horizontally at the height of 2 m or above from the ground care is taken that the pollarded stump head is not split. The head is covered with mud/straw to prevent it from drying. A stone slab is placed on the head to facilitate the uniform sprouting of new shoots around the stump. During the cyclical / subsequent pollarding, the pollarded stumps that coppices profusely are allowed to grow till the harvest of the first year’s crop. On the second year, some 4 to 5 selected shoots are retained and the rest removed. These shoots are allowed to grow till the next *jhum* cycle and the same process is repeated. Thus with the incorporation of alder trees in their *jhum* lands, the farmers are able to obtain higher productivity while at the same time avoid loss of soil fertility.

5. Promotion of indigenous knowledge-based innovations for sustainable development

Today traditional knowledge systems are seen as pivotal above all discussions on sustainable socio-economic development and poverty alleviation in developing countries (Brokensha *et. al*., 1980; Warren, 1990; Gupta, 1992). The focus on traditional knowledge represents a shift away from the preoccupation with the centralised, technically oriented solutions of past decades, which failed to improve the prospects of most of the world's peasants and small farmers (Agarwal, 1996). It has been demonstrated that the exclusion of such knowledge from development activities has had disastrous consequences in every region of the world where outsider knowledge has been imposed without regard to traditional knowledge (Cashman, 1989).

A number of literatures, however, have argued that the traditional knowledge has its limitations (e.g., Reijntjes *et. al*., 1992; Bebbington, 1993; Howard and Widdowson, 1996). Some researchers (e.g., Arce and Long, 1992) argued that it needed to be formalised, since it is essentially of a fragmented and provisional nature. It is in this formalisation phase that problems with respect to the application of traditional knowledge are most likely to arise. The collection of this from diverse indigenous sources is often a laborious, time-consuming and costly process.

It was not until the mid-1980s, after recognising the shortcomings of Farming Systems Research and Development, it was argued that researchers would not need the knowledge generated but should concentrate more on complementing their technical innovations with the local knowledge of farmers, in a participatory research and development process (Chambers, 1983; Richards, 1985). This idea was supported by international research institutes, which already had a number of innovations that only needed minor adaptations by local farmers.

Indigenous knowledge-based innovation would aim at using the indigenous knowledge in the earlier stages of technology/ innovation development. It is argued in this paper that we start learning from the systems of indigenous knowledge and practices that have stood the test of time. The use of indigenous knowledge in the development of agricultural innovations led to many surprising successes. Most authors give emphasis to the need of hybridising indigenous and formal scientific knowledge (e.g. Nanda, 1999; Rosenblum *et al*., 2001; Marschke and Nong, 2003). Positive experiences have been reported especially in the fields of land and water resource management (Mendoza and Luning, 1997; Stein *et al*., 2001; Marothia, 2002) and use of indigenous knowledge on medicinal plants (Vandebroek *et al.*, 2004).

Some authors, however, claim the irreconcilability of local indigenous and formal scientific knowledge; the latter being biased too much by political or commercial interests. Further, scaling up the use of indigenous knowledge in innovation development appears to present problems in spite of enough evidence from success stories. Scaling up is seen as internally inconsistent as a result of the very local character of the knowledge. Simpson (1999), therefore, proposes the development of expert information systems, based on best of both local and formal knowledge. He further suggests that innovation programmes should provide their own learning environment and evolution, similarly to the adaptability that farmers have shown in their agricultural and economic performance. For technology development by incorporating indigenous knowledge systems into agricultural research, Rajasekaran (1994) suggested that there is need for inter-disciplinary approach, identifying problems, recording relevant indigenous knowledge systems, conducting participatory on-station research, conducting on-farm farmer oriented research, evaluating technological options, etc.

The sustainable development can only be achieved by developing a science based on the priorities of the local people, and by creating a technological base that includes both traditional and modern approaches to problem solving. Sustainable development might be better served by a system that incorporates both traditional and scientific knowledge systems (Icamina, 1993). The expectation that traditional perspectives and perceptions should play an important role in planning and implementing socio-economic development programmes is yet to be fulfilled. This is mostly attributable to the failure to develop an adequate mechanism for integrating the traditional knowledge with formal (scientific) decision-making practices.

In a concept paper[+] Rahman (2000) reviewed relevant theories, concepts, methods and empirical understanding to address the problem, "How to develop an effective framework to incorporate local knowledge systems into formal or scientific processes and procedures for resource management in developing countries?" and he came out with the following conclusions:

(i) The framework should be able to generate an adaptive, participatory and iterative decision-making process.

(ii) The framework should be able establish an equitable relation between traditional knowledge and scientific knowledge systems through an ongoing process of dialogue and partnership building among the stakeholders (local communities, scientists, managers and policy makers). This framework should allow a variety of participatory research methods for collection o traditional knowledge.

(iii) The framework should allow cognitive transformation of both the traditional knowledge and scientific knowledge among the stakeholders. Also, the framework should be supported by an automated part comprising of a comprehensive GIS and hypertext conversion facilities for processing, organising and presenting the integrated knowledge base.

6. Conclusions

There is much to be learned from indigenous knowledge systems of local people. As it is seen from the cases of indigenous agriculture of Northeast India, the traditional agricultural practices evolved from these knowledge systems are performing well even today without bringing much ecological degradation. Devaluing indigenous knowledge systems as "low productive," "primitive," and "old" is no longer a useful attitude. Keeping this indigenous knowledge as the basis during the process of developing technologies and innovations would result in the production of sustainable technological options. People in the formal scientific

[+] This paper is entitled "A Participatory DSS to Incorporate Local Knowledge for Resources and Environmental Management in Developing Countries" and published on the web (internet) at www.fes.uwaterloo.ca/u/marahman/PhD_Comprehensive.html knowledge system should grasp the importance of local or indigenous knowledge and also might need to get out of the old mode of thinking. Thus, bringing a desirable change in the attitudes and behaviours of researchers and extensionists would stimulate the process of incorporating indigenous knowledge systems into agricultural research and extension. With our ecology and environment today facing severe questions of sustainability it is the right time now to focus on ecologically friendly and economically viable innovations. Certain ecologically viable and sustainable innovations that still see the light today offer tremendous opportunities for incorporating them with the modern science. The blended technologies/ innovations from the two systems should be able to retain the ecological strength of the indigenous knowledge and at the same time be able to derive and demonstrate from the modern science, a good amount of productivity.

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